

PROGRAM: 7009

NAME: MATRIX MULTIPLIER

AUTHOR: E. C. MAZZA

COMPLETED: August 28, 1964

DESCRIPTION:

This program will compute the product of N number of matrices [A] [B] ---- [N]. The program has an option of computing the product of [A] [B] [A] T when matrices [A] [B] are entered. The size of matrices (L_m) are limited and can be determined by the following method:

$$L_m = [(A_i \cdot A_j) + (B_i \cdot B_j)] \times 2$$

Where

A = matrix A
B = matrix B
i = rows.
j = columns

L_m for Cinch I may not exceed 1000.
 L_m for Cinch III may not exceed 500.

OPERATING INSTRUCTIONS:

- 1) Data is entered via paper tape using the following format. The matrix is punched by rows with a "D" preceding the first the first data point and an "E" following the last data point of each matrix.
- 2) Set tab stops at 12, 23, 32, 41 and 50.
- 3) Enter program PB-2003C in the tape reader and type "R." Upon entry of PB-2003C the indicator light will come on, at this point type "R" again, this will transfer control to the program.
- 4) Insert data tape in tape reader and type the following:

D A_ic/r
A_jc/r
B_i^jc/r
B_jc/r
E

Where

- A_i = number of rows of A matrix
- A_j = number of columns of A matrix
- B_i = number of rows on B matrix
- B_j = number of columns of B matrix

Upon the typing of "E" the program will begin and upon completion the product of $[A][B]$ will be printed out.

To compute the product of N number of MATRICES, follow steps #1 thru #4 and proceed as follows:

- 5) Upon the completion of step #4 the resultant matrix C will be printed out and the computer will halt. At this point, insert the data tape for the new matrix in the tape reader. To restart the program merely depress and raise the enable and breakpoint switches.
- 6) Upon completion of step #5 the operand lights will show a reading of 07, indicating entry by keyboard.
- 7) At this point, enter the size of the new matrix as follows:

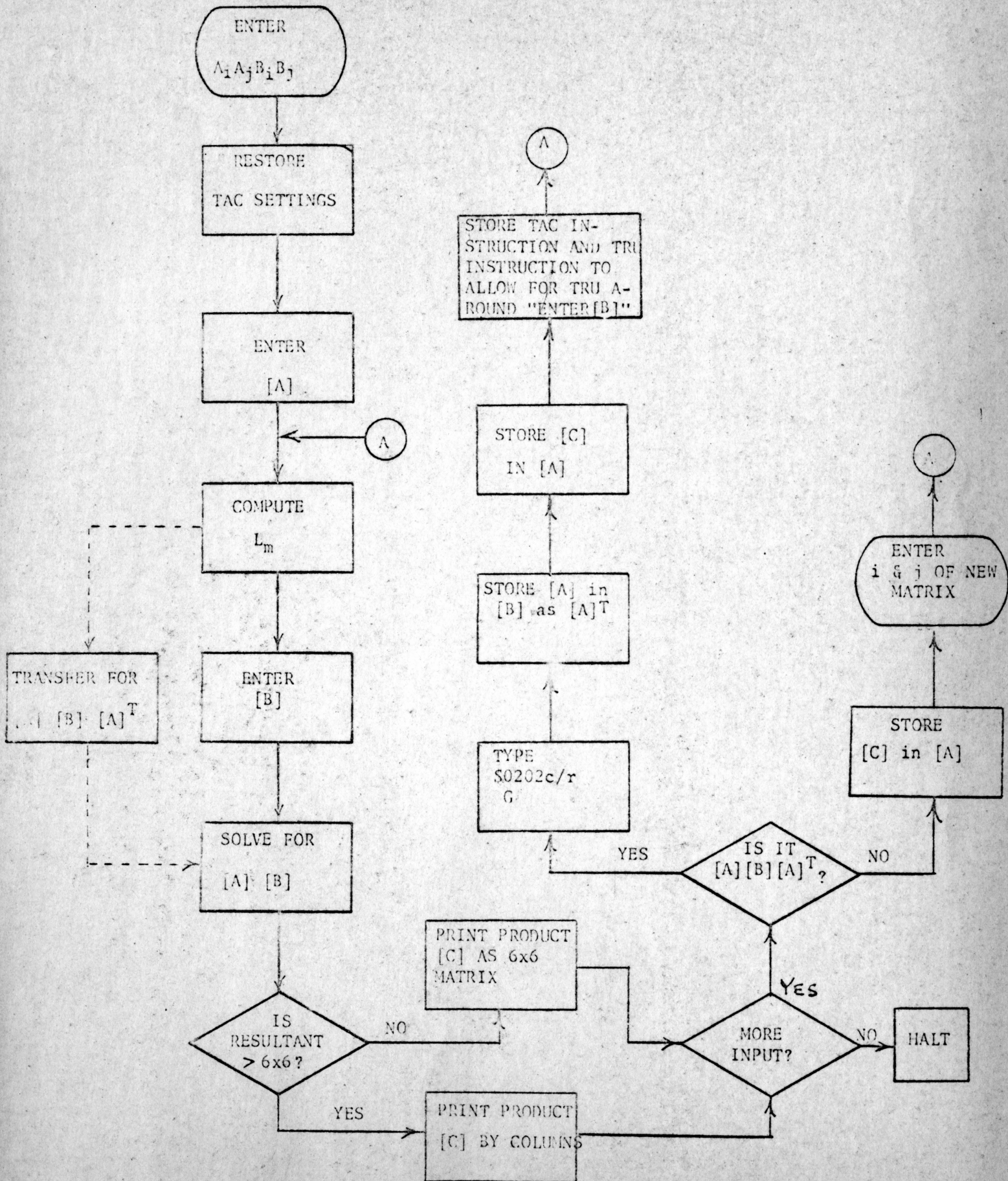
Type "D" number of rows c/r
 number of columns c/r
 "E"

Upon typing the "E" the program will begin computation.

- 8) To compute the product of N number of matrices, repeat steps #5 thru #7.

To compute the product of $[A][B][A]^T$ follow steps #1 thru #4 and proceed as follows:

- 9) Upon completion of step #4 the computer will halt (04 on the operand lights), at this point depress the enable and breakpoint switches, type I and raise the enable and breakpoint switches.
- 10) Type \$0202 c/r G this will restart the program and solve for the product of $[A][B][A]^T$.



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PB250 CINCH CODING SHEET

PROGRAM NAME MATRIX MULTIPLIER PAGE 1 OF 13

PROGRAM NO. 7009 SPECIAL I.D. _____

BY E. C. Mazza DATE 8/27/64

L C O D E	LOCATION	C O D E	INSTRUCTION			SYM. O P C O D E	NOTES	
			T	O P	I R			ADDRESS
L	0001	c/r C		16		0490	RTK	AiAjBiBj
	2			10		0304	CAD	sta A sib
	3			60		0102	STA	
	4			10		0306	CAD	tac sib
	5			60		0168	STA	
	6			10		0308	CAD	
	7			60		0262	STA	
	8			12		0500	RPT	[A]
	9			10		0490	CAD	Ai
	0010			14		0492	MUP	Ai
	1			12		0000	ADD	
	2			60		0380	STA	2(AiAj)
	3			60		0382	STA	2(AiAj)
	4			22		0316	SUB	2
	5			60		0384	STA	2(AiAj)-2
	6			60		0386	STA	2(AiAj)-2
	7			10		0494	CAD	Bi
	8			14		0496	MUP	Bj
	9			12		0000	ADD	
	0020			60		0388	STA	2(BiBj)
	1			60		0390	STA	2(BiBj)
	2			22		0316	SUB	2
	3			60		0392	STA	2(BiBj)-2
				60		0394	STA	2(BiBj)-2
	5			10		0492	CAD	Ai
	6			12		0000	ADD	
	7			60		0396	STA	2Aj
	8			60		0398	STA	2Aj
	9			22		0316	SUB	2
	0030			60		0400	STA	2Aj-2

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PB 250 CINCH CODING SHEET

PROGRAM NAME MATRIX MULTIPLIER PAGE 2 OF 13

PROGRAM NO. 7009 SPECIAL I.D. _____

BY _____ DATE 8/27/64

L C O D E	LOCATION	C O D E	INSTRUCTION			SYM. OP CODE	NOTES
			T	OP	R ADDRESS		
	0 031			60		0402	STA 2Aj-2
	2			22		0316	SUB 2
	3			60		0404	STA 2Aj-4
	4			60		0406	STA 2Aj-4
	5			10		0496	CAD Bj
	6			12		0000	ADD
	7			60		0408	STA 2Bj
	8			60		0410	STA 2Bj
	9			22		0316	SUB 2
	0 040			60		0412	STA 2Bj-2
	1			60		0414	STA 2Bj-2
	2			22		0316	SUB 2
	3			60		0416	STA 2Bj-4
	4			60		0418	STA 2Bj-4
	5			10		0490	CAD Ai
	6			14		0496	MUP Bj
	7			12		0000	ADD
	8			60		0420	STA 2AiBj
	9			60		0422	STA 2AiBj
	0 050			22		0316	SUB 2
	1			60		0424	STA 2(AiBj)-2
	2			60		0426	STA 2(AiBj)-2
	3			10		0380	CAD 2(AiAj)
	4			12		0388	ADD 2(BiBj)
	5			60		0428	STA 2(AiAj)+2(BiBj)
	6			60		0430	STA 2(AiAj)+2(BiBj)
	7			12		0424	ADD 2(AiBj)-2
	8			60		0432	STA 2(AiAj)+2(BiBj)+2(AiBj)-2
	9			60		0434	STA 2(AiAj)+2(BiBj)+2(AiBj)-2
	0 060			10		0428	CAD 2(AiAj)+2(BiBj)

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PB 250 CINCH CODING SHEET

PROGRAM NAME MATRIX MULTIPLIER PAGE 3 OF 13

PROGRAM NO. 7009 SPECIAL I.D. _____

BY E. C. Mazza DATE 8/27/64

L C O D E	L O C A T I O N	C O D E	I N S T R U C T I O N			S Y M. O P C O D E	N O T E S	
			T	O P	I R			A D D R E S S
	0061			22		0408	SUB	2Bj
	2			60		0436	STA	$2(A_iA_j)+2(B_iB_j)-2B_j$
	3			60		0438	STA	$2(A_iA_j)+2(B_iB_j)-2B_j$
	4			10		0380	CAD	$2(A_iA_j)$
	5			12		0412	ADD	$2B_j-2$
	6			60		0440	STA	$2(A_iA_j)+2B_j-2$
	7			60		0442	STA	$2(A_iA_j)+2B_j-2$
	8			10		0420	CAD	$2(A_iB_j)$
	9			12		0384	ADD	$2(A_iA_j)-2$
	0070			60		0444	STA	$2(A_iB_j)+2(A_iA_j)-2$
	1			60		0446	STA	$2(A_iB_j)+2(A_iA_j)-2$
	2			10		0380	CAD	$2(A_iA_j)$
	3			12		0416	ADD	$2B_j-4$
	4			60		0448	STA	$2(A_iA_j)+2B_j-4$
	5			60		0450	STA	$2(A_iA_j)+2B_j-4$
	6			10		0496	CAD	B_j
	7			22		0314	SUB	1
	8			60		0452	STA	B_j-1
	9			10		0490	CAD	A_i
	0080			14		0408	MUP	$2B_j$
	1			22		0408	SUB	$2B_j$
	2			60		0454	STA	$A_i2B_j-2B_j$
	3			60		0456	STA	$A_i2B_j-2B_j$
	4			10		0428	CAD	$2(A_iA_j)+2(B_iB_j)$
	5			12		0454	ADD	$A_i2B_j-2B_j$
	6			60		0458	STA	$2(A_iA_j)+2(B_iB_j)+A_i2B_j-2B_j$
	7			60		0460	STA	$2(A_iA_j)+2(B_iB_j)+A_i2B_j-2B_j$
	8			10		0380	CAD	$2(A_iA_j)$
	9			12		0416	ADD	$2B_j-4$
	0090			60		0462	STA	$2(A_iA_j)+2B_j-4$

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PB250 CINCH CODING SHEET

PROGRAM NAME MATRIX MULTIPLIER PAGE 4 OF 13

PROGRAM NO. 7009 SPECIAL I.D. _____

BY E. C. Mazza DATE 8/27/64

L C O D E	LOCATION	C O D E	INSTRUCTION			SYM. OP CODE	NOTES	
			T	OP	I R			ADDRESS
	0091			60		0494	STA	$2(A_iA_j)+2B_j-4$
	2			10		0428	CAD	$2(A_iA_j)+2(B_iB_j)$
	3			12		0412	ADD	$2B_j-2$
	4			60		0466	STA	$2(A_iA_j)+2(B_iB_j)+2B_j-2$
	5			60		0468	STA	$2(A_iA_j)+2(B_iB_j)+2B_j-2$
	6			22		0316	SUB	2
	7			60		0470	STA	$2(A_iA_j)+2(B_iB_j)+2B_j-4$
	8			60		0472	STA	$2(A_iA_j)+2(B_iB_j)+2B_j-4$
	9			10		0380	CAD	$2(A_iA_j)$
	0100			22		0396	SUB	$2A_j$
	1			60		0474	STA	$2(A_iA_j)-2A_j$
	2			60		0476	STA	$2(A_iA_j)-2A_j$
	3			02	A	0380	SIB	$2(A_iA_j)$
	4			03	A	0316	SIM	2
	5			04	A	0380	SIL	$2(A_iA_j)$
	6			17	A	0500	RPT	[B]
	7			06	A	0106	MIT	
	8			02	D	0310	SIB	0
	9			03	D	0314	SIM	1
	0110			04	D	0452	SIL	B_j-1
	1			02	C	0430	SIB	$2(A_iA_j)+2(B_iB_j)$
	2			03	C	0316	SIM	2
	3			04	C	0468	SIL	$2(A_iA_j)+2(B_iB_j)+2B_j-2$
	4			02	B	0382	SIB	$2(A_iA_j)$
	5			03	B	0410	SIM	$2B_j$
	6			04	B	0438	SIL	$2(A_iA_j)+2(B_iB_j)-2B_j$
	7			02	A	0312	SIB	0
	8			03	A	0316	SIM	2
	9			04	A	0402	SIL	$2A_j-2$
	0120			10		0294	CAD	0

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PB 250 CINCH CODING SHEET

PROGRAM NAME MATRIX MULTIPLIER PAGE 5 OF 13
 PROGRAM NO. 7009 SPECIAL I.D. _____
 BY E. C. Mazza DATE 8/27/64

L C O D E	LOCATION	C O D E	INSTRUCTION			SYM. OP CODE	NOTES
			T	OP	I R		
	0121			60	C	0500	STA [C]
	2			10	A	0500	CAD [A]
	3			14	B	0500	MUP [B]
	4			12	C	0500	ADD [C]
	5			60	C	0500	STA [C]
	6			06	A	0127	MIT
	7			06	B	0122	MIT
	8			10		0382	CAD base B
	9			12		0316	ADD 2
	0130			60		0382	STA base B
	1			10		0438	CAD limit B
	2			12		0316	ADD 2
	3			60		0438	STA limit B
	4			06	C	0114	MIT
	5			10		0312	CAD base A
	6			12		0396	ADD 2Aj
	7			60		0312	STA base A
	8			10		0430	CAD base C
	9			12		0408	ADD 2Bj
	0140			60		0430	STA base C
	1			10		0402	CAD limit A
	2			12		0396	ADD 2Aj
	3			60		0402	STA limit A
	4			10		0468	CAD limit C
	5			12		0408	ADD 2Bj
	6			60		0468	STA limit C
	7			10		0380	CAD 2(AiAj)
	8			60		0382	STA base B
	9			10		0436	CAD 2(AiAj)+2(BiBj)-2Bj
	0150			60		0438	STA limit B

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PB 250 CINCH CODING SHEET

PROGRAM NAME MATRIX MULTIPLIER PAGE 6 OF 13
 PROGRAM NO. 7009 SPECIAL I.D. _____
 BY E. C. Mazza DATE 8/27/64

L C O D E	LOCATION	C O D E	INSTRUCTION			SYM. O P C O D E	NOTES	
			T	O P	I R			ADDRESS
	0 151			06	D	0111	MIT	
	2			10		0294	CAD	0
	3			60		0312	STA	base A
	4			10		0428	CAD	$2(A_iA_j)+2(B_iB_j)$
	5			60		0430	STA	base C
	6			10		0466	CAD	$2(A_iA_j)+2(B_iB_j)+2B_j-2$
	7			60		0468	STA	limit C
	8			10		0380	CAD	$2(A_iA_j)$
	9			60		0382	STA	base B
	0 160			10		0436	CAD	$2(A_iA_j)+2(B_iB_j)-2B_j$
	1			60		0438	STA	limit B
	2			10		0400	CAD	$2A_j-2$
	3			60		0402	STA	limit A
	4			10		0496	CAD	B_j
	5			30		0322	CAM	6
	6			32		0262	TCH	
	7			46		0324	TAC	heading
	8			46		0337	TAC	resultant AB
	9			02	A	0468	SIB	$2(A_iA_j)+2(B_iB_j)+2B_j-2$
	0 170			03	A	0410	SIM	$2B_j$
	1			04	A	0434	SIL	$2(A_iA_j)+2(B_iB_j)+2A_iB_j-2$
	2			02	B	0430	SIB	$2(A_iA_j)+2(B_iB_j)$
	3			03	B	0316	SIM	2
	4			04	B	0472	SIL	$2(A_iA_j)+2(B_iB_j)+2B_j-4$
	5			26	B	0500	TNT	[C]
	6			06	B	0175	MIT	
	7			27	A	0500	TNC	[C]
	8			10		0430	CAD	base B
	9			12		0408	ADD	$2B_j$
	0 180			60		0430	STA	base B

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PB250 CINCH CODING SHEET

PROGRAM NAME MATRIX MULTIPLIER PAGE 7 OF 13

PROGRAM NO. 7009 SPECIAL I.D. _____

BY E. C. Mazza DATE 8/27/64

L C O D E	LOCATION	C O D E	INSTRUCTION			SYM. O P C O D E	NOTES	
			T	O P	I R			ADDRESS
	0181			10		0472	CAD	limit B
	2			12		0408	ADD	2Bj
	3			60		0472	STA	limit B
	4			06	A	0172	MIT	
	5			10		0428	CAD	$2(A_iA_j)+2(B_iB_j)$
	6			60		0430	STA	base B
	7			10		0470	CAD	$2(A_iA_j)+2(B_iB_j)+2B_j-4$
	8			60		0472	STA	limit B
	9			00		0000	HLT	
	0190			02	A	0430	SIB	$2(A_iA_j)+2(B_iB_j)$
	1			03	A	0316	SIM	2
	2			04	A	0434	SIL	$2(A_iA_j)+2(B_iB_j)+2A_iB_j-2$
	3			02	B	0312	SIB	0
	4			03	B	0316	SIM	2
	5			04	B	0386	SIL	$2(A_iA_j)-2$
	6			10	A	0500	CAD	[C]
	7			60	B	0500	STA	[A]
	8			06	A	0199	MIT	
	9			06	B	0196	MIT	
	0200			16		0494	RTK	Bi and Bj
	1			40		0009	TRU	
	2			10		0494	CAD	Bi
	3			30		0496	CAM	Bj
	4			34		0296	TCU	point error
	5			02	C	0310	SIB	0
	6			03	C	0316	SIM	2
	7			04	C	0402	SIL	$2A_i-2$
	8			02	B	0382	SIB	$2(A_iA_i)$
	9			03	B	0316	SIM	2
	0210			04	B	0442	SIL	$2(A_iA_i)+2B_i-2$

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PB 250 CINCH CODING SHEET

PROGRAM NAME MATRIX MULTIPLIER PAGE 8 OF 13
 PROGRAM NO. 7009 SPECIAL I.D. _____
 BY E. C. Mazza DATE 8/27/64

L C O D E	LOCATION	C O D E	INSTRUCTION			SYM. OP CODE	NOTES
			T	O P	I R		
	0 211			02	A	0 312	SIB 0
	2			03	A	0 398	SIM 2Aj
	3			04	A	0 476	SIL 2(AiAj)-2Aj
	4			10	A	0 500	CAD [A]
	5			60	B	0 500	STA [B] = [A] ^T
	6			06	A	0 217	MIT
	7			06	B	0 214	MIT
	8			10		0 312	CAD base A
	9			12		0 316	ADD 2
	0 220			60		0 312	STA base A
	1			10		0 476	CAD limit A
	2			12		0 316	ADD 2
	3			60		0 476	STA limit A
	4			10		0 382	CAD base B
	5			12		0 408	ADD 2Bj
	6			60		0 382	STA base B
	7			10		0 442	CAD limit B
	8			12		0 408	ADD 2Bj
	9			60		0 442	STA limit B
	0 230			06	C	0 208	MIT
	1			10		0 294	CAD 0
	2			60		0 312	STA base A
	3			10		0 380	CAD 2(AiAj)
	4			60		0 382	STA base B
	5			10		0 474	CAD 2(AiAj)-2Aj
	6			60		0 476	STA limit A
	7			10		0 440	CAD 2(AiAj)+2Bj-2
	8			60		0 442	STA limit B
	9			02	A	0 312	SIB 0
	0 240			03	A	0 316	SIM 2

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PB 250 CINCH CODING SHEET

PROGRAM NAME MATRIX MULTIPLIER PAGE 9 OF 13
 PROGRAM NO. 7009 SPECIAL I.D. _____
 BY E. C. Mazza DATE 8/27/64

L C O D E	LOCATION	C O D E	INSTRUCTION			SYM. OP CODE	NOTES	
			T	O P	I R			ADDRESS
	0 241			04	A	0 386	SIL	$2(A_i A_j) - 2$
	2			02	B	0 430	SIB	$2(A_i A_j) + 2(B_i B_j)$
	3			03	B	0 316	SIM	2
	4			04	B	0 434	SIL	$2(A_i A_j) + 2(B_i B_j) + 2A_i B_j - 2$
	5			10	B	0 500	CAD	[C]
	6			60	A	0 500	STA	[A]
	7			06	B	0 248	MIT	
	8			06	A	0 245	MIT	
	9			10		0 490	CAD	A _i
	0 250			60		0 480	STA	temp
	1			10		0 496	CAD	B _j
	2			60		0 492	STA	A _j
	3			10		0 480	CAD	temp
	4			60		0 496	STA	B _j
	5			10		0 298	CAD	0108 sta tru
	6			60		0 102	STA	
	7			10		0 300	CAD	A tac sib
	8			60		0 168	STA	
	9			10		0 302	CAD	tac tac
	0 260			60		0 262	STA	
	1			40		0 009	TRU	
	2			46		0 324	TAC	heading
	3			46		0 337	TAC	resultant
	4			02	A	0 310	SIB	0
	5			03	A	0 314	SIM	1
	6			04	A	0 452	SIL	B _j -1
	7			05	A	0 482	STB	
	8			46		0 360	TAC	col
	9			10		0 482	CAD	base
	0 27 0			12		0 314	ADD	1

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PB250 CINCH CODING SHEET

PROGRAM NAME MATRIX MULTIPLIER PAGE 10 OF 13
 PROGRAM NO. 7009 SPECIAL I.D. _____
 BY E. C. Mazza DATE 8/27/64

L C O D E	LOCATION	C O D E	INSTRUCTION			SYM. O P C O D E	NOTES
			T	O P	I R		
	0 27			60		0 484	STA col. no.
	2			61		0 000	FIX
	3			35		0 002	SFL
	4			27		0 484	TNC col. no.
	5			62		0 000	FLO
	6			35		0 009	SFL
	7			02	B	0 430	SIB $2(A_iA_j)+2(B_iB_j)$
	8			03	B	0 410	SIM $2B_j$
	9			04	B	0 434	SIL $2(A_iA_j)+2(B_iB_j)+2A_iB_j-2$
	0 28 0			27	B	0 500	TNC [C]
	1			06	B	0 280	MIT
	2			46		0 359	TAC c/r c/r
	3			10		0 430	CAD base B
	4			12		0 316	ADD 2
	5			60		0 430	STA base B
	6			10		0 434	CAD limit B
	7			12		0 316	ADD 2
	8			60		0 434	STA limit B
	9			06	A	0 267	MIT
	0 29 0			10		0 428	CAD $2(A_iA_j)+2(B_iB_j)$
	1			60		0 430	STA base B
	2			10		0 432	CAD $2(A_iA_j)+2(B_iB_j)+2A_iB_j-2$
	3			60		0 434	STA limit B
	4			00		0 000	HLT
	5			00		0 000	HLT
	6			46		0 362	TAC error
	7			00		0 000	HLT
	8			60		0 476	STA
	9			40		0 108	TRU
	0 30 0			46		0 346	TAC

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PB 250 CINCH CODING SHEET

PROGRAM NAME MATRIX MULTIPLIER PAGE 11 OF 13
 PROGRAM NO. 7009 SPECIAL I.D. _____
 BY E. C. Mazza DATE 8/27/64

L C O D E	LOCATION	C O D E	INSTRUCTION			SYM. O P C O D E	NOTES	
			T	O P	I R			ADDRESS
	0301			02	A	0468	SIB	
	2			46		0324	TAC	
	3			46		0346	TAC	
	4			60		0476	STA	
	5			02	A	0380	SIB	
	6			46		0337	TAC	
	7			02	A	0468	SIB	
	8			46		0324	TAC	
	9			46		0337	TAC	
L	0310	c/r D				0		0
	1					0		
	2					0		0
	3					0		
	4					0		1
	5					0		
	6					0		2
	7					0		
	8					0		2
	9					0		
	0320					0		4
	1					0		
	2					0		6
	3					0		
L	0324	c/r A				0		c/r PROGRAM PB-2003C
	5					0		MATRIX MULTIPLIER c/r ;
	6					0		
	7					0		
	8					0		
	9					0		
	0330					0		

pb Packard Bell Computer

PB250 CINCH CODING SHEET

PROGRAM NAME MATRIX MULTIPLIER PAGE 12 OF 13
 PROGRAM NO. 7009 SPECIAL I.D. _____
 BY E. C. Mazza DATE 8/27/64

L C O D E	LOCATION	C O D E	INSTRUCTION				SYM. O P C O D E	NOTES
			T	O P	I R	ADDRESS		
	0 33					0		
	2					0		
	3					0		
	4					0		
	5					0		
	6					0		
L	033	c/r A				0	RESULTANT uc lcAuc lcBuc lc c/r ;	
	8					0		
	9					0		
	0 34					0		
	1					0		
	2					0		
	3					0		
	4					0		
	5					0		
L	034	c/r A				0	RESULTANT uc lcAuc lcBuc lcAuc lc	
	7					0	TRANSPosed c/r;	
	8					0		
	9					0		
	0 35					0		
	1					0		
	2					0		
	3					0		
	4					0		
	5					0		
	6					0		
	7					0		
	8					0		
L	035	c/r A				0	c/r c/r ;	
L	0 36	c/r A				0	col;	

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PB 250 CINCH CODING SHEET

PROGRAM NAME MATRIX MULTIPLIER PAGE 13 OF 13

PROGRAM NO. 7009 SPECIAL I.D. _____

BY E. C. Mazza DATE 8/27/64

L C O D E	LOCATION	C O D E	INSTRUCTION			SYM. OP CODE	NOTES
			T	O P	I R		
	0 36 1					0	
L	036 2	c/r A				0	MATRIX uc lcBuc lc IS NOT SQUARE-
	3					0	SOLUTION IMPOSSIBLE c/r ;
	4					0	
	5					0	
	6					0	
	7					0	
	8					0	
	9					0	
	0 37 0					0	
	1					0	
	2					0	
	3					0	
	4					0	
	5					0	
	6					0	
	7					0	
	37 8					0	E
	9					0	
	0 38 0					0	
	1					0	
	2					0	
	3					0	
	4					0	
	5					0	
	6					0	
	7					0	
	38 8					0	
	9					0	
	0 39 0					0	